

# Manufacturing Simulation and Visualization

Program Manager: Charles R McLean  
 Total FTE: 11  
 Total Funding: \$1,110,000

## Goal

Identify, specify, prototype, test, and evaluate data interfaces and methods for integrating manufacturing simulation and visualization applications with each other and with other manufacturing software to reduce the cost, increase the accessibility, and improve the interoperability of manufacturing simulation technology for U.S. industry.

## Program Objectives

### FY2000

Develop mechanisms and interfaces for accelerating the development of simulation models and virtual manufacturing worlds (including teach programming of simulated human operations using virtual reality interfaces).

#### ***SIMA (Systems Integration for Manufacturing Applications) Simulation of Manual Manufacturing Operations***

Develop languages, visualization techniques, data models, and testing methodologies for representing and visualizing manufacturing systems and their components within simulation environments, particularly in the area of modeling humans in the manufacturing environment.

### FY2000

Develop testbed and testing capabilities to evaluate architectures, interface specifications, and enhanced virtual reality capabilities for modeling and simulation.

#### ***Advanced Technology Program (ATP) Simulation-based Adaptive Learning Systems***

Develop testbed and testing capabilities to evaluate architectures, interface specifications, and enhanced virtual reality capabilities for using modeling and simulation technology in the development of adaptive learning systems.

### FY2001

Specify and promote standardization of architectures and interfaces for the development of modular distributed simulation environments.

#### ***OMG (Object Management Group) /SDX Manufacturing and Simulation Standards Support***

Specify and promote standardization of data interfaces between simulation applications and other upstream/downstream manufacturing applications (e.g., process specification, control programming, MRP (Material Resource Planning) /ERP (Enterprise Resource Planning), plant layout, product designs, scheduling, business process modeling, inventory, and maintenance).

#### ***Intelligent Manufacturing Systems (IMS) MISSION Simulation Architectures, Interfaces, and Data Models***

Specify and promote standardization of architectures and interfaces for the development of modular distributed simulation environments from the supply chain to the process level for IMS MISSION.

### FY2002

Develop experimental prototype simulation models and systems that push current technology (e.g., distributed manufacturing simulations, modular composable simulation environments, enterprise/supply chains, and manual manufacturing operations).

### ***Navy Maritech NASSCO***

Develop experimental prototype simulation models and systems that push current technology in the area of shipyard simulations (e.g., distributed manufacturing simulations, modular composable simulation environments, enterprise/supply chains, manual manufacturing operations).

### ***Intelligent Manufacturing Systems (IMS) MISSION Distributed Manufacturing Simulation Prototypes***

Develop experimental prototype simulation models and systems that push current technology (e.g., distributed manufacturing simulations, modular composable simulation environments, enterprise/supply chains, manual manufacturing operations).

### ***Navy Maritech Atlantic Marine Shipyard Simulation Development***

Develop experimental prototype simulation models and systems that push current technology in the area of shipyard simulations (e.g., distributed manufacturing simulations, modular composable simulation environments, enterprise/supply chains, manual manufacturing operations).

### **FY2005**

Establish and advance the science base for manufacturing simulation and simulation system integration through collaborative research with manufacturers, simulation software vendors, standards organizations, and the academic research community.

### **FY2005**

Develop languages, visualization techniques, data models, and testing methodologies for representing and visualizing manufacturing systems and their components within simulation environments.

### **FY2005**

Develop methodologies for the validation of manufacturing decisions using manufacturing simulation, including business models, processes, schedules, and manufacturing system designs.

### **FY2005**

Specify and promote standardization of neutral formats and library access mechanisms for storing and exchanging multi-level component models of manufacturing systems and resources.

## **Customer Needs**

Industry experts on manufacturing technology have recognized the importance of simulation and visualization. Various industry roadmap efforts, such as the Integrated Manufacturing Technology Roadmapping (IMTR), National Research Council (NRC) Visionary Manufacturing Challenges, and NEMI have made strong recommendations for research in modeling and simulation technology. The IMTR Study stated that "Modeling and simulation (M&S) are emerging as key technologies to support manufacturing in the 21st century, and no other technology offers more than a fraction of the potential that M&S does for improving products, perfecting processes, reducing design-to-manufacturing cycle time, and reducing product realization costs." (source: "IMTR Roadmap for Modeling and Simulation," Integrated Manufacturing Technology Roadmapping Project Office, Oak Ridge Centers for Manufacturing Technology, Oak Ridge, TN)

Simulation and modeling was also recently identified by the NRC, as one of two breakthrough technologies that will accelerate progress in addressing the grand challenges facing manufacturing in 2020. (source: "Visionary Manufacturing Challenges for 2020," National Research Council, Washington, DC 1998) The study goes on to recommend advancement of "the state of the art by establishing standards for the verification, validation, and accreditation of modeling tools and models (including geometric models, behavioral models, process models, cost models, and performance models). ...Fulfillment of the recommendation would provide fundamental building blocks for the dynamic models and 'real-time' simulations

of 2020.” The study recommends research and development in: “standards for software compatibility or robust software that does not need standards, ... methods to make data accessible to everyone (protocols, security, format, and interoperability), ... interactive, 3-D, simulation-based visualizations of complex structures integrating behavioral, organizational, and people issues with other analyses, ... methods to merge historical data with simulation systems, ... simulation of alternative business processes.”

How broad is the manufacturing simulation software domain? Examples of current manufacturing simulation applications include: modeling and verification of discrete and continuous manufacturing processes (e.g., machining, injection molding, sheet metal forming, semiconductor fabrication, and refining), offline equipment programming (robots), system layout planning, material flow analysis, process and system visualization, ergonomic analysis of work areas and manual tasks, evaluation of schedules, and business process modeling. Hundreds, if not thousands, of commercial simulation software products are currently marketed to support these and other areas. It is likely that the number and types of simulation applications will continue to grow rapidly in the coming years. For the most part, these software applications do not interoperate with each other, or with other manufacturing systems that need to share data.

Independent economic studies have estimated the size of the manufacturing simulation and visualization software market in the range of \$650 million dollars by the 2001 time frame. Detailed information on the simulation market has been difficult to come by since a number of companies in this sector are not publicly owned. Precise financial data on the overall market is probably not available. In any case, the NIST Manufacturing Simulation and Visualization (MS&V) program has been successful in attracting a number of major U.S. simulation companies as participants and supporters of

its projects, including: Autosimulations, Pritsker-Symix, Deneb Robotics, Systems Modeling Corporation, Promodel, KBSI, Tecnomatix, Engineering Animation Inc. (EAI). Other companies are discussing participation in our program activities. Program staff have established dialogs and obtained support from the top management in many of these companies. Active participation in the MS&V program by these companies will help ensure the implementation and impact of project results.

Although studies have recognized the potential of manufacturing simulation and visualization, there are a number of technical and economic barriers that hinder the use of this technology. Industry expense for implementing simulation technology is much greater than the cost of computing hardware, peripheral devices, software licenses, and maintenance. Typically companies must factor in the cost of salaries and training for simulation and support staff, translation of existing company data, systems integration of applications, and development and maintenance of models. These costs are likely to be much greater than the initial acquisition costs for the simulation software and hardware.

Vendors and industrial users alike have recognized that the development and maintenance of production systems and resources models is very costly. For example, the development of a detailed simulation model of a single machine tool may take an engineer four to six weeks. Models must now be custom developed for each simulation software package. The development of neutral, vendor independent data formats for storing simulation models could greatly improve the accessibility of simulation technology to U.S. industry by enabling the sharing and re-use of models. Such neutral simulation model formats could be used by individual companies, simulation vendors, equipment and resource manufacturers, consultants, and service providers to develop sharable models. Neutral formats would help enlarge the market for simulation models and make their

development a viable business enterprise.

The development of neutral data formats for simulation models is an area in which the NIST MS&V program can have a major impact. The program is uniquely positioned with its neutrality, expertise, and testbed capabilities to support industry in the development of these neutral component models, related simulation technology, and interface standards to integrate manufacturing simulation systems. Top management in a number of simulation software vendors (Deneb Robotics, Systems Modeling Corporation, Autosimulations, and Dassault Systems) have already endorsed NIST's initial plans to develop neutral vendor-independent formats for simulation-component models. Near-term MS&V activities will focus on architectures, interfaces, and data models that will enable the development of vendor neutral simulation model libraries.

## Technical Approach

Standardized interfaces, component model libraries, and modeling techniques promise to reduce the cost and increase the accessibility of manufacturing simulation technology for U.S. industry. A major focus for the MS&V program is the identification and specification of data interfaces for various manufacturing simulation applications. The program was formally organized in fiscal year (FY) 1999 through the Manufacturing Systems Integration Division (MSID) strategic planning efforts. It has grown out of past projects in engineering tool integration and scheduling system integration funded by the Systems Integration for Manufacturing Applications (SIMA) program and the Navy Manufacturing Science and Technology Program. These projects used simulation systems, but the focus of these projects was not simulation standards per se.

The program has actively worked to establish collaborations with industry, software

vendors, universities, and guest researchers to leverage resources and bring diverse technical expertise and backgrounds to the program. The program will achieve its near-term objectives through joint work carried out with external collaborators under the SIMA Program, the international Intelligent Manufacturing Systems Program, the Navy Maritech Program, and the Object Management Group (OMG) Special Interest Group in Distributed Simulation (SIMSIG). The Initial Manufacturing Exchange Specification (IMES) methodology, developed for the SIMA Program, is being used to develop candidate simulation standards.

The technical approach of the MS&V Program is to: 1) identify critical manufacturing process and system simulation domains and associated types of simulation software applications, 2) analyze current and future trends for simulation and testing technology, 3) establish specification and testing methods, models, and metrics for validating simulation systems interfaces, 4) identify tools and models to be used in the specification development, prototyping, and testing processes, 5) construct a test bed containing simulation applications, prototype integration, testing tools, and test cases, 6) specify and develop architectures, data models, and interface specifications for integrating simulation applications, component modules, and reference libraries, 7) conduct experimental tests, industry demonstrations, and reviews to substantiate the validation and testing process itself, and 8) promote specifications as candidate standards within the national and international standards community.

## Standards Participation

- **OMG Simulation Special Interest Group (SIMSIG):** Program staff have supported the standardization activities within the Object Management Group (OMG) Simulation Special Interest Group (SIMSIG) that is part of its Manufacturing Domain Task Force for the past two years. SIMSIG is focusing on the development of CORBA-based interfaces for the implementation of distributed simulations. During this period, SIMSIG established the High Level Architecture (HLA) as a standard. NIST is currently working with the Defense Modeling and Simulation Office (DMSO) to evaluate the suitability of the HLA standard to manufacturing simulation.

## Accomplishments

- **September FY1999 Developed IMS MISSION architecture -** A major goal of MISSION is the specification of neutral interfaces for the integration of manufacturing simulation systems. NIST was asked to lead Work Package 2 that is focusing on the development of architectures, data models, and interface specifications for distributed simulation. Copies of simulation models, data specifications, and test cases have been requested by and provided to industrial users, software vendors, and academic researchers.
- **July FY1998 Organized U.S. Team for IMS MISSION Project -** Due to the recognition that NIST simulation research had received internationally, we were invited to organize a U.S. team for an Intelligent Manufacturing Systems (IMS) simulation project by Japanese and European representatives. The IMS "Modeling and Simulation Environments for Design Planning and Operation of Globally Distributed Enterprises," or MISSION, project was approved and initiated in 1998 with more than 50 organizations participating internationally. The strength of the U.S. team is notable, given that it is based upon voluntary participation that was organized by NIST. Among the U.S. team members are the following organizations: 1) government: NIST, Defense Modeling and Simulation Office (DMSO, represented by MITRE Corporation), 2) industry: Black & Decker, TRW, 3) simulation software vendors: Deneb Robotics, ProModel Corporation, Pritsker/Symix Systems, Autosimulations, Systems Modeling Corporation, Knowledge Based Systems, Inc. (KBSI), Tecnomatix Technologies, Inc., and 4) academic: University of Kentucky, Virginia Polytechnic Institute and State University, Florida International University, Arizona State University, Michigan Technological University, North Carolina A&T State University, University of Wisconsin, University of Tennessee, Nyamekye Research and Consulting Firm, University of Illinois, Penn State University, and Iowa State University.
- **December FY1997 Developed Initial Manufacturing Exchange Specification (IMES) requirements document for discrete event simulation.**
- **December FY1997 Established Cooperative Research and Development Agreements (CRADAs) with major manufacturers, such as Black and Decker, and simulation vendors such as Deneb Robotics.**
- **December FY1997 Developed industrial needs document for production system engineering and production management - scheduling.**

- October FY1997 Established simulation testbed at NIST that has capabilities and resources that are probably unique throughout the world. Many of the major U.S. simulation software products are now available within our laboratories to support research, development, and interface specification activities. These capabilities enabled NIST staff and guest researchers to get “hands on” experience with state-of-the-art simulation technology and interface issues facing simulation developers and system integrators. NIST researchers developed prototype simulations and system integrations.
- December FY1996 Developed prototype simulated machine shop.
- December FY1995 Established a manufacturing simulation testbed comprised of a number of commercial simulation products and manufacturing system models.